Fuels

Expanding Clean Fuel and Feedstock Resources

Introduction

Program Areas

- Transportation Fuels and Chemicals
- Solid Fuels and Feedstocks
- Advanced Fuels Research

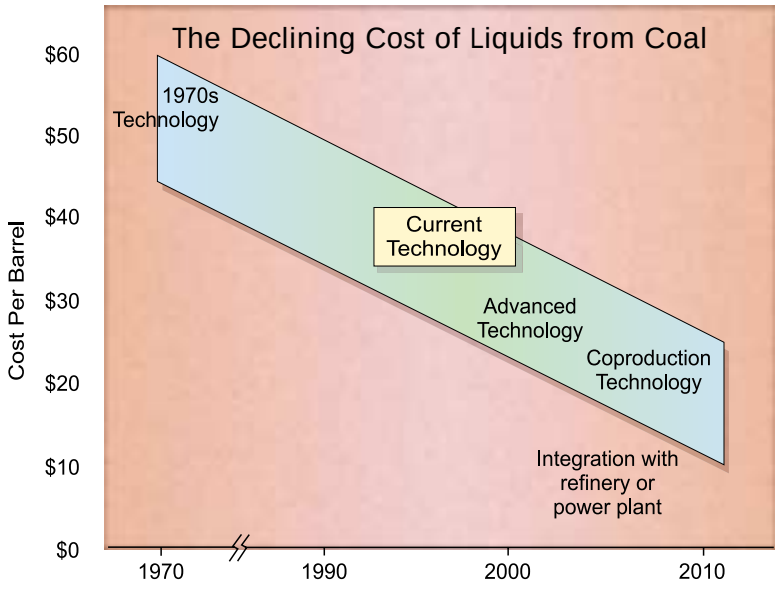
The need for liquid fuels is forecast to be a critical element of this Nation's energy future in the 21st century.

Using abundant, domestic coal resources to produce fuels and chemicals, instead of imported petroleum, can act as a cushion against future oil price increases and reduce the Nation's reliance on imported oil. It also could serve as the core of a new domestic industry that would produce a slate of alternative fuels that would meet increasingly stringent environmental standards and help boost fuel efficiencies in the Nation's transportation fleet.

The Coal & Power Systems (C&PS) Fuels program seeks to ensure the development and demonstration of environmentally responsible coal-based technologies that produce ultra-clean transportation fuels, utility and boiler fuels, chemicals, and carbon products for metallurgical and industrial applications. By conducting research in advanced fuel science — hydrogen separation and storage technologies, catalyst development, and conversion processes for converting solids and gases to gasoline and diesel fuels — the C&PS Fuels program is providing affordable conversion technologies to exploit coal's potential for producing a wide array of valuable fuels and other products. This research is undertaken in conjunction with industry and other federal agencies.

The Transportation Fuels and Chemicals program area encompasses several approaches to produce ultra-clean transportation fuels for use in high-efficiency vehicles and light- and heavy-duty trucks. The Solid Fuels and Feedstocks program area examines the environmental and economic benefits of co-firing biomass and waste feedstocks with coal, develops tailored feedstocks for making premium carbon products, and provides the means to remove trace contaminants from coal.

The advances in technology for coproducing power, fuels, and chemicals will enable the Nation to use its plentiful fossil resources to fulfill a broader range of energy and chemical feedstock needs while reducing impacts to the environment.



Historically, the obstacle to producing coal-based liquid fuels has been cost. In the late 1970s, the projected cost of coal liquids approached $60 per barrel. With today's technology, costs have been reduced to below $35 per barrel. By integrating Early Entrance Coproduction Plants with existing petroleum refining facilities and using coal combined with low–cost feedstocks, such as petroleum coke and wastes, costs are projected to go even lower — perhaps to the $25 per barrel range.

Fuels Program Benefits

National Benefits

- Reduces emissions through efficiency gains;
- Use of ultra-clean transportation fuels provides an alternative supply of transportation fuels from domestic resources, thus hedging against security risk; and
- Reduces the U.S. balance of payments.

Supplier Benefits

- Boosts fuels development processing efficiencies leading to lower capital and maintenance costs which, in turn, influences supplier economics;
- Provides, through gasification-based coal conversion, a way to store energy from a power plant during off-peak periods when demand is low; and
- Allows for flexibility in affordable, substitute feedstocks for power generation.

Customer Benefits

- Protects against price shocks in the transportation fuels arena;
- Dramatically improves the mileage efficiency of transportation vehicles;
- Ensures reliability of fuel supply; and
- Improves economics of fuels, chemicals, and power through coproduction.

Drivers

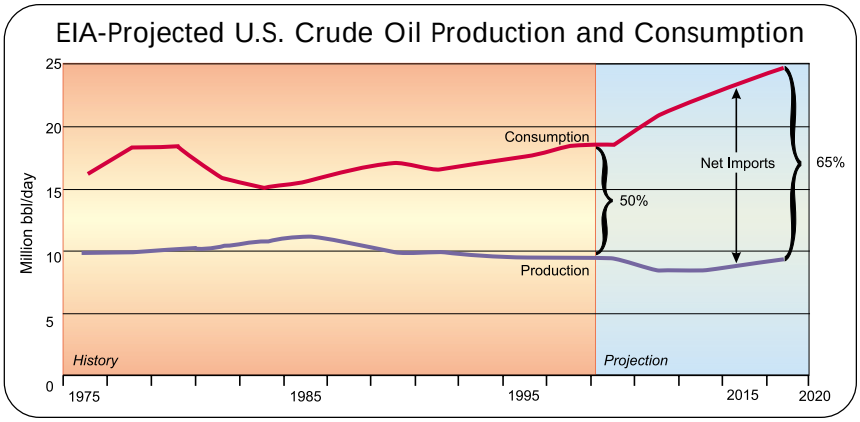
Environmental Regulations. Transportation accounts for approximately 473 million metric tons (MMT) of carbon emissions, or 32 percent of total U.S. carbon emissions. The Energy Information Administration (EIA) projects that, by 2020, total carbon emissions in the United States will increase to 1,975 MMT under business-as-usual assumptions with transportation accounting for 665 MMT, or 34 percent of total U.S. carbon emissions. In addition, of the total manmade air emissions in the United States, highway transportation is responsible for 57 percent of the carbon monoxide (CO), almost one-third of the nitrogen oxides (NO_x), and almost one-third of the volatile organic compounds. Combinations of these pollutants are responsible for ground level ozone that can significantly impact public health. Dramatic increases in vehicle numbers and miles traveled have been forecast by the Energy Information Administration. This growth will lead to greater transportation pollution unless significantly improved fuel/vehicle systems are developed and deployed. Much effort from both industry and government is currently directed toward improving fuel/vehicle systems. From this effort it is clear that success in obtaining high efficiency and low emissions can only be achieved by simultaneously improving the engine, the exhaust after-treatment, and the fuel.

There also is a host of potential regulatory actions that could require major additional reductions in energy-related emissions during the next decade. Likewise, restructuring in the electric utility industry will place market pressures on utilities to find low-cost approaches to meeting stringent environmental regulations for potentially hazardous air pollutants.

Energy Security. The EIA also predicts that, by 2020, U.S. petroleum imports (already representing over 50 percent of consumption) will rise to 65 percent and increase our negative balance of payments. Currently, the United States imports approximately 11 million barrels per day of crude oil and finished products, 50 percent of which comes from the Organization of Petroleum Exporting Countries (OPEC). At current world oil market prices, oil imports cost the U.S. almost $90 billion per year.

Projections of brisk growth in domestic and world oil demand substantially change the energy security outlook. Excessive reliance on a single geographic area to satisfy increased world demand for oil creates the potential for oil-importing nations to be vulnerable to supply disruptions and price volatility.

Further, petroleum is a finite resource, production of which will eventually peak and decline in the face of continually increasing demand. It cannot be known with any degree of certainty when this peak in production will occur. However, current estimates of ultimately recoverable conventional oil (approximately 2.7 trillion barrels) and projected world oil demand have led experts to predict a peak in petroleum production occurring around the year 2015 and declining thereafter. While there may be 2.7 trillion barrels of petroleum more than currently assessed, these additional resources are likely to reduce the rate of decline rather than increase peak production. As conventional oil resource production approaches its peak and eventual decline, there is the risk that the price of oil will rise significantly and permanently. This risk can be minimized through development of fuels from alternative domestic sources.



Tier II Emission Standards

On December 21, 1999, the U.S. Environmental Protection Agency (EPA) issued the final Tier II emissions regulations that were proposed in May 1999. The rule sets new, much more stringent exhaust emission standards for light-duty vehicles and establishes new maximum sulfur levels in gasoline.

The regulations focus on reducing emissions of ozone-forming gases, including nitrogen oxides and non-methane organic gases, and particulate matter from these vehicles. The standards, expressed in grams of pollutants emitted per mile (g/mi), apply to all new passenger cars, light light-duty trucks (LLDT), heavy light-duty trucks (HLDT), and medium-duty passenger vehicles (MDPV) regardless of the vehicle or engine size. Under this approach, which reflects the EPA's concern about the increasing market share and emissions from minivans and sport utility vehicles, larger vehicles will have to employ cleaner engine and emissions control technologies than those needed for smaller vehicles and engines. The same requirements will apply to all vehicles regardless of the fuel (i.e., gasoline- and diesel-fueled vehicles will be certified to the same emissions standards).

	Tier II Standard	**Phase-In Period**
New Vehicle NO_x Levels		
– Passenger and LLDT	0.07 g/mi	2004–2007
– HLDT and MDPV	0.07 g/mi	2008–2009
Gasoline Sulfur Levels	120–300	2000–2004
(in parts per million)	30–80	2004–2006
Particulate Matter		
– Passenger, LLDT, and HLDT	0.00–0.02 g/mi	2000–2006
– MDPV	0.00–0.02 g/mi	2000–2008

ACCOMPLISHMENTS

The C&PS Fuels program is developing and commercializing advanced technologies for carbon-based solid materials and fuels that will maintain U.S. industrial competitiveness, contribute to efficient power production, and promote environmental quality.

Air Product's LaPorte coal liquefaction test facility contributes to R&D efforts that ensure future availability of clean, affordable coal-derived fuels.

A number of significant successes have already been achieved by the program. For example, the Microcel® flotation column, developed with DOE support, has had significant commercial success in coal and mineral applications, with over 50 units in use worldwide. Other successes include development of the MicroMag® heavy-medium cycloning process for coal cleaning, and the GranuFlow® process for improved coal fines handling.

Two Clean Coal Technology (CCT) projects addressed the conversion of low-energy-density, low-sulfur western coals into high-energy-density, very low-sulfur products. ENCOAL's demonstration of the Liquids-from-Coal Process successfully completed operation in July 1997, and the technology is moving toward commercialization. During the demonstration, nearly 260,000 tons of raw coal were processed into 120,000 tons of solid process-derived fuel and more than 121,000 barrels of coal-derived liquid. A cross section of customers consumed almost all of the product.

Western Syncoal Partnership's demonstration of the Advanced Coal Conversion Process (ACCP) continues to operate under an eight-year contract to supply a high-energy-density, low-sulfur solid Syncoal® fuel to Montana Power's 330-MWe Colstrip No. 2 unit using a dedicated pneumatic feed system. Through fiscal year 2000, the ACCP facility had processed over 2.6 million tons of raw coal to produce over 1.7 million tons of Syncoal®.

As research progresses in the Fuels program from laboratory to bench-scale experiments, the advances in specific areas of the fuel production system are incorporated into production of specific products at the LaPorte, Texas proof-of-concept unit. This approach has worked very successfully over the past 15 years, as exemplified by the Liquid Phase Methanol Process (LPMEOH™) whereby technical viability was proven at LaPorte and is now being demonstrated at commercial scale by the Eastman Chemical Company. More recently, successful operations at LaPorte included production of Fischer-Tropsch liquids and dimethyl ether, both of which are of interest to industry for their potential use as premium fuels.

With the recent successes of the LPMEOH™ process, the market for clean-burning, storable liquid fuel from coal is more promising than ever. The LPMEOH™ process demonstration plant, located at Eastman Chemical Company's chemicals-from-coal complex in Kingsport, Tennessee, began its fourth year of operation on April 2, 2000, and has produced in excess of 66 million gallons of methanol from coal-derived synthesis gas. Due to its accomplishments, the project was extended recently until March 2003. As part of the project, a product-use test program has been developed to enhance the early commercialization of this type of clean coal technology processing facility. The objective of the testing program is to demonstrate commercial market application for the LPMEOH™-derived methanol as a replacement fuel and as a fuel supplement in the 2000–2003 timeframe. Specifically, methanol from the LPMEOH™ project has been made available for seven different tests to determine its feasibility as a feedstock in transportation and power generation applications.

ACTIVITIES

The C&PS Fuels program response to the environmental, energy security, and economic challenges now and into the future is to provide the technical basis for a clean fuels industry capable of producing transportation fuels and chemicals from coal and other carbonaceous, non-petroleum resources.

The roadmap on page 4-9 provides an overview of the activities under the Fuels program. Specifically, research is focused on developing ultra-clean transportation fuels, feedstocks for power generation that will help to lower emissions, and high-value carbon products. Technology development in these research and development areas will ensure coal's continued role in the Nation's energy future.

Transportation Fuels and Chemicals

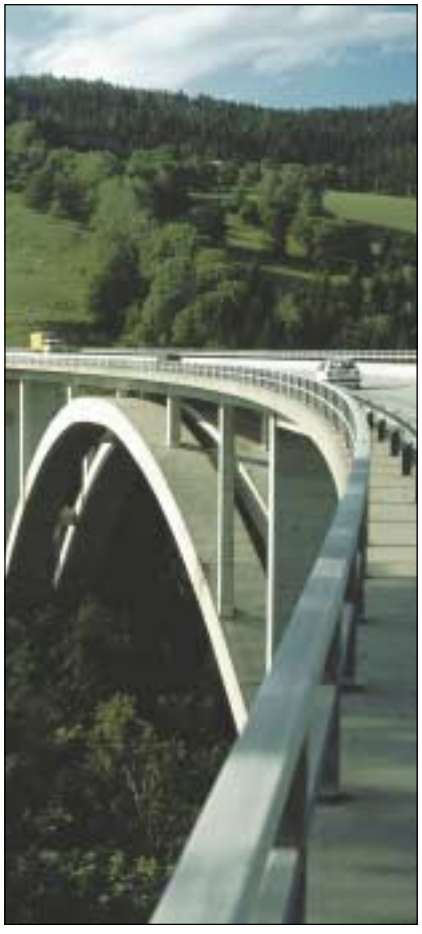
This program area encompasses several approaches to produce ultra-clean transportation fuels for use in high-efficiency vehicles and light- and heavy-duty trucks. The major R&D activities include: (1) feedstock conversion R&D; (2) reactor/process development; (3) early entrance coproduction plant; (4) product upgrading; and (5) systems engineering. These activities provide the technical underpinning to the Ultra-Clean Transportation Fuels Initiative (UCTFI), which is funded under the Oil and Gas Program budget within DOE's Office of Fossil Energy (FE) in fiscal year 2001.

Coal-Based Synthesis Gas Conversion R&D. R&D is currently focused on the generation and production of synthesis gases (i.e., a mixture of carbon monoxide and hydrogen) and the subsequent catalytic conversion of the synthesis gas to liquid fuels and other products. Fischer-Tropsch (F-T) synthesis provides the best available means for conversion of natural gas- or coal-derived synthesis gas to clean transportation fuels. DOE's Fuels program is pursuing process improvements including the development of more efficient F-T reactors, more active and robust slurry catalysts, efficient product upgrading, and methods that produce hydrogen more economically.

Early Entrance Coproduction Plant (EECP). The Fuels program is cosponsoring the development of the EECP technologies with Central Systems Integrated Gasification Combined-Cycle (IGCC) program. These gasification-based plants would coproduce some combination of power, fuels, and chemicals with high efficiency and reduced capital cost, thus facilitating early commercial entry of both IGCC power and coal-derived fuels and chemicals. Three industry project teams were selected by DOE in 1999 to pursue industry/government cost-shared research and engineering studies that will be directed toward privately funded design, construction, and operation by 2007 of first-of-a-kind commercial facilities that coproduce multiple products.

Ultra-Clean Transportation Fuels Initiative. Concurrent with the EECP effort will be the development of ultra-clean fuels for the 21st century through the UCTFI in partnership with the Natural Gas Processing and the Petroleum Processing programs. In February 2000, DOE issued a solicitation to industry for research and development of ultra-clean fuels and fuel conversion processes. Round I project selections occurred in September 2000. Round II project selections are expected in early March 2001.

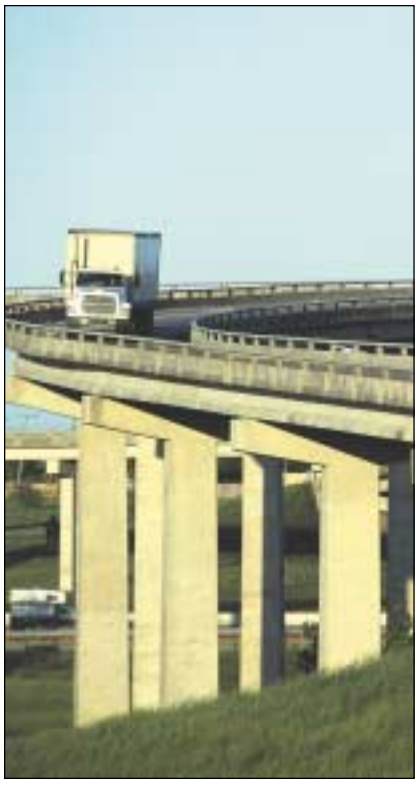
In conjunction with midterm field testing of the UCTFI fuels and fuel conversion processes, laboratory testing for characterization of product quality, including emissions testing in engines, will also be conducted. UCTFI Round I projects are expected to yield results in the 2004–2005 timeframe.



Solid Fuels and Feedstocks

The Solid Fuels and Feedstock program area is developing and commercializing advanced technologies for processing carbon-based solid materials with the ultimate goal of sustaining a coal-based carbon products industry. Activities are organized into environmental solid fuels, tailored carbon feedstocks, and premium carbon industry.

Environmental Solid Fuels. Research in this area will result in the more efficient use of solid fuels and includes pilot-scale testing of an electrostatic separation process for dry, fine-size coal and proof-of-concept (POC) testing of an advanced flotation control system. Industrial-scale testing of an advanced technology will also be conducted for the production of carbonized slurry fuels for power production from coal, biomass, and waste.



Work will also continue on the development of a national coal quality database on trace elements. Cooperation with a broad-based, utility-sector consortium for coal utilization called the Upgraded Coal Interest Group will investigate coal desulfurization; removal of trace elements; upgrading of low-rank coals; technology for utilization of fine-coal products; and the preparation and utilization of new fuels, including coal-water slurries and coal/biomass/waste composites. DOE's participation extends (at present) until 2005. In that time, DOE will have access to, and will participate in, technology transfer reports expected to flow from the group.

Tailored Carbon Feedstocks. The Tailored Carbon Feedstocks activity concentrates on advanced technologies for the development of premium carbon products from coal and the preparation of specially designed (tailored) feedstocks for the production of advanced transportation fuels and chemicals from coal, biomass, and waste feeds. Current projects focus on economically recovering carbon through novel coal fines processing devices as well as dewatering/reconstituion systems.

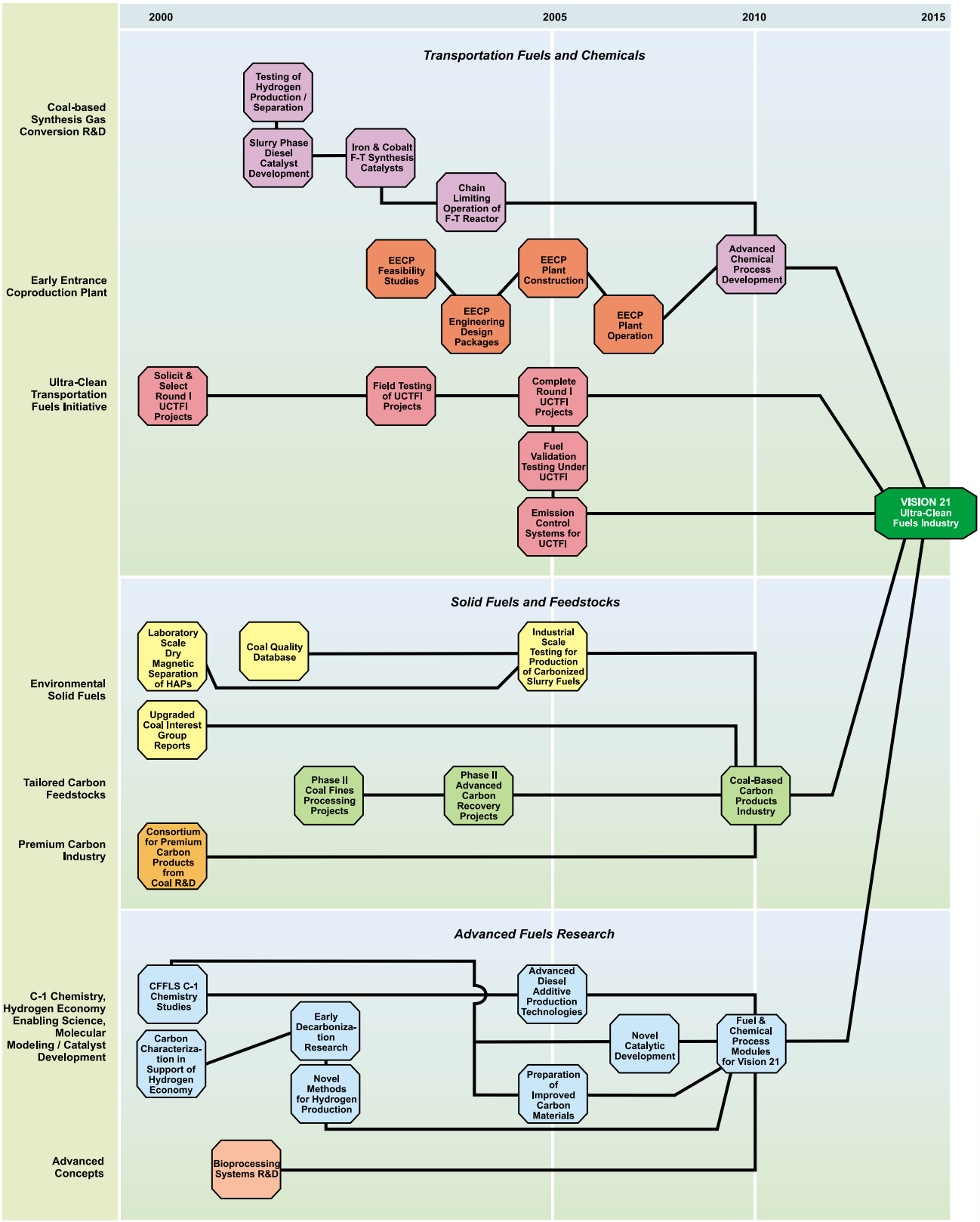
Premium Carbon Industry. The primary focus of this research is to study ways to extract carbon from coal for producing such materials as carbon electrodes and carbon fibers for high-strength materials, and to reduce carbon dioxide from the coal-to-liquids process. The main activity focuses on development of an industry-driven consortium for the development of premium carbon products from coal. Research, development, demonstration, and commercial application programs will be determined for investigating technologies for non-fuel uses of coal, including production of lightweight premium carbon products that will be used in the transportation industry—airplanes, cars, lightweight trucks, passenger vans, and sport utility vehicles. These new technologies will substantially reduce transportation vehicle weight and yield major improvements in fuel efficiency and environmental quality.

Advanced Fuels Research

The Advanced Fuels Research program area provides the scientific foundation for technology development in the Transportation Fuels and Chemicals program area, and develops concepts that will help address the challenges associated with Vision 21.

This long-term research centers on developing significantly improved and innovative technologies that produce economically competitive fuels with minimal environmental impact, and with reduced by-product CO_2 production. Examples of such technologies include: (1) innovative, coal-derived fuel technology that produces fuels at lower costs with less energy usage; (2) hybrid, renewable and fossil energy technology as part of Vision 21 concepts to produce fuels, electricity, chemicals, and carbon products with improved environmental performance and with less CO_2; (3) computational methods to improve catalyst development and experimental evaluation; and (4) bioprocessing systems that produce liquid transportation fuels with less CO_2 production. These technologies will provide the longer-term modular processes to be used in Vision 21 plants, which would produce energy and fuels products in a manner consistent with global climate change strategies.

Fuels Program Roadmap



Drivers

- EPA standards will require cleaner burning transportation fuels in order to reduce air pollutants including carbon monoxide, nitrogen oxides, volatile organic compounds, and particulate matter.
- Environmental and economic incentives will encourage the reduction of solid wastes associated with coal production and utilization.
- The U.S. economy is almost totally dependent on oil for its transportation needs.
- By 2015, it is projected that the demands for petroleum in non-industrialized countries will nearly double, and the U.S. will be importing more than 60 percent of its oil, much of which will come from the Middle East.
- The high level of imports have worrisome energy security and economic implications, through the potential for supply disruptions with the attendant economic dislocations, and negative balance of payments.
- Deregulation will place market pressures on utilities to find low-cost approaches to meet stringent environmental regulations for potentially hazardous air pollutants.
- The expanding export market for cost-effective coal technologies that are attractive to coal-intensive developing countries will lead to the creation of jobs, reduction of trade deficits, and improved regional and global environments.

Objectives

- Provide the technology base for a clean fuels industry capable of producing transportation fuels and chemicals from coal and other carbonaceous, non-petroleum domestic resources.
- Foster the development of advanced technologies to enable the efficient use of coal, biomass, and waste fuels while addressing environmental concerns associated with hazardous air pollutant and greenhouse gas emissions, and waste disposal issues.
- Develop a coal-based U.S. carbon products industry.
- Conduct the fundamental and exploratory research needed to support the fuels and chemical production aspects of Vision 21 technologies, and improved methods of producing liquid transportation fuels.

Strategies

- Successfully complete demonstration and product use test program of Liquid Phase Methanol CCT project.
- Advance three-phase slurry reactor technology to cost-effectively produce premium fuels, diesel-fuel blending compounds, or high-value chemicals from coal or natural gas.
- Deploy one or more Early Entrance Coproduction Plants that demonstrate the feasibility of producing some combination of power, fuels, and chemicals from coal.
- Continue support for, and participation in, engine/vehicle development and testing efforts.
- Through the Ultra-Clean Transportation Fuels Initiative, identify needs of transportation industry and select R&D projects to achieve ultra-clean fuels for transportation.
- Conduct research on advanced technologies for the reduction of greenhouse gases and for low-cost precombustion control of hazardous air pollutant precursors.
- Conduct research on technologies to enhance carbon recovery from coal and coal wastes and improve coal fines processing.
- Support the industry-led, cost-shared consortium to develop, demonstrate, and commercialize technologies for non-fuel uses of coal.
- Conduct research and early development of improved innovative concepts for Vision 21 modules.

Performance Measures

- To have the capability to produce 2 million barrels/day of premium transportation fuels, blendstocks, and additives. (2020)
- To have the capability to produce, by 2008, ultra-clean fuels that will help vehicles to meet EPA Tier II standards. (2008)
- To deploy commercially scalable, fully integrated coproduction plants that demonstrate the technical, economic, and environmental benefits of producing multiple products from gasification-based technologies. (2007)
- To increase output of U.S. finished carbon products five fold, while increasing core domestic employment from 50,000 to 150,000. (2010)
- To have fuel and chemical process modules as components of Vision 21 facilities or as stand-alone plants; and to meet requirements and schedules of advanced vehicle development program for clean fuels. (2020)

Clean Diesel from the Fischer-Tropsch Process

Indirect conversion of any hydrocarbon fuel involves: (1) gasification of the hydrocarbon source to produce syngas (a mixture of carbon monoxide and hydrogen), and (2) conversion of the syngas utilizing F-T chemistry to produce a transportation fuel product. The F-T process uses various catalysts to produce linear hydrocarbons and oxygenates, including unrefined gasoline, diesel, and wax ranges, which can be further refined to produce additional diesel fuel.

Today, there is significant commercial interest in F-T technology for producing diesel fuels that are primarily C10 to C20 paraffins. Current F-T chemistry leads inevitably to the production of waxes (or C20+ hydrocarbons), meaning as much as 50 weight percent of the F-T product needs to undergo post-synthesis treatment, such as hydro-cracking. This adds to capital cost and process complexity. If this cost can be eliminated, F-T synthesis of diesel fuels becomes much more cost competitive.

Research activities in the Transportation Fuels and Chemicals program area are focused on improving the chemistry of the F-T process by optimizing the catalyst and reaction conditions in order to maximize conversion of syngas, while producing a maximum diesel fuel-potential product mixture. Development work on iron and cobalt catalysts involves the preparation and evaluation of new, improved formulation for F-T synthesis. The emphasis is on achieving higher levels of activity, selectivity, and stability and the development of catalyst/wax separation techniques for use in slurry phase reactors.

Transportation Fuels and Chemicals

The Transportation Fuels and Chemicals program area supports R&D technologies to produce ultra-clean transportation fuels, chemicals, and carbon products.

These technologies convert coal into liquid fuels and chemicals in two steps. In the first step, coal is gasified in the presence of oxygen and steam to generate a gas containing mostly carbon monoxide and hydrogen (i.e., synthesis gas). In the second step, the synthesis gas, after being cleaned of impurities, is converted into a variety of products. These products include:

- Hydrocarbon fuels, such as gasoline, diesel fuel, and jet fuel.
- Oxygenated compounds, such as alcohol fuels (e.g., methanol), and oxygenated fuel additives (e.g., ethers and esters).
- Premium chemicals, such as olefins and paraffinic wax.

Research within the Transportation Fuels and Chemicals program area is focused on developing clean fuels that: (1) are environmentally superior to those derived from conventional petroleum-based fuels; (2) can supplement the liquid fuel requirements of the Nation's transportation sector; (3) will use the existing transportation fuels infrastructure; and (4) will help engine and vehicle manufacturers achieve higher performance with significantly lower emissions in both conventional and advanced systems.

The research efforts address key technical issues associated with making premium fuels and chemicals and provide the foundation upon which to pursue initiatives such as the Liquid Phase Methanol project currently being demonstrated in the CCT program; the Early Entrance Coproduction Plant initiative that is co-sponsored with Gasification Technologies; and the Ultra-Clean Transportation Fuels Initiative, which is jointly sponsored by Transportation Fuels and Chemicals, Natural Gas Processing, and Petroleum Processing programs.

Projects within this program areas currently emphasize the following.

Process Development

- Continued improvements in the three-phase slurry reactor technology where technology advances have shown significant productivity improvements.
- Development of low-cost iron-based catalysts for the slurry reactor, especially for their application and suitability to feedstocks that are low in hydrogen content such as coal, wastes, and petroleum coke.
- Separation techniques for both gaseous and liquid products to remove contaminants.

Product Testing/ Evaluation

- Laboratory characterization of product quality, including emissions tests in engines.

Systems Engineering

- Extensive life-cycle analyses to identify those areas of fuel conversion processing that offer the best opportunities for CO_2 mitigation.

Concurrently, R&D is underway on novel methods to reduce production of greenhouse gases through process improvements and co-firing of multiple feeds such as waste material or biomass. Each of these projects is examining process details within the context of a system that is intended to make a specific product.

The following describes some of the key elements of the Transportation Fuels and Chemicals program area's research and key initiatives that are being emphasized over the next several years:

Ultra-Clean Transportation Fuels Initiative

Over the next several years, the United States will implement new, stricter federal and state clean air requirements for highway vehicles; encounter greater volatility in global energy markets; face increased economic competition in the international market for clean highway vehicles and fuels production technologies; and confront the threat of global climate change. Given this emerging situation, it is clear that R&D must be pursued aggressively to develop advanced technologies for high-efficiency, low-emissions highway vehicles, as well as for the production of ultra-clean fuels required for their operation. Furthermore, it is imperative that the Nation accelerate the transition toward the increased use of diversified domestic feedstocks, including natural gas, coal, and renewables to ensure the availability of these ultra-clean transportation fuels.

DOE's Office of Fossil Energy (FE) has created a strategic alliance among its petroleum, natural gas

NETL's Ultra-Clean Fuels Science and Technology

Presently, vehicle tailpipe emissions of unburned hydrocarbons and NO_x are dependent on the performance of catalytic systems. However, the performance of a vehicle's catalytic converter is degraded by very small amounts of sulfides present in the exhaust gases. An integrated technology development effort that encompasses fuels, engines, and after-treatment systems will be required in the near future.

The NETL Ultra-Clean Fuels Science and Technology research aims to develop the science for pollution-free, highly efficient, and affordable transportation systems. Ultra-Clean Fuels Science and Technology efforts will include research into hydrogen separation membrane technology, nano-scale storage of hydrogen, conversion of natural gas to liquid fuels free of sulfur and nitrogen, next-generation catalysts, analytical techniques to measure and characterize extremely low levels of sulfur, and environmentally acceptable oxygenated fuels.

Combined with the fuels R&D in C&PS, NETL's activities will strengthen the technical foundation available to ensure the success of this Nation's future energy plants by leveraging research by the DOE's Office of Science, EERE, the National Science Foundation, and the Department of Defense. NETL is also partnering with universities, other national laboratories, and the private sector, as well as participating in DOE's Ultra Clean Transportation Fuels Initiative.

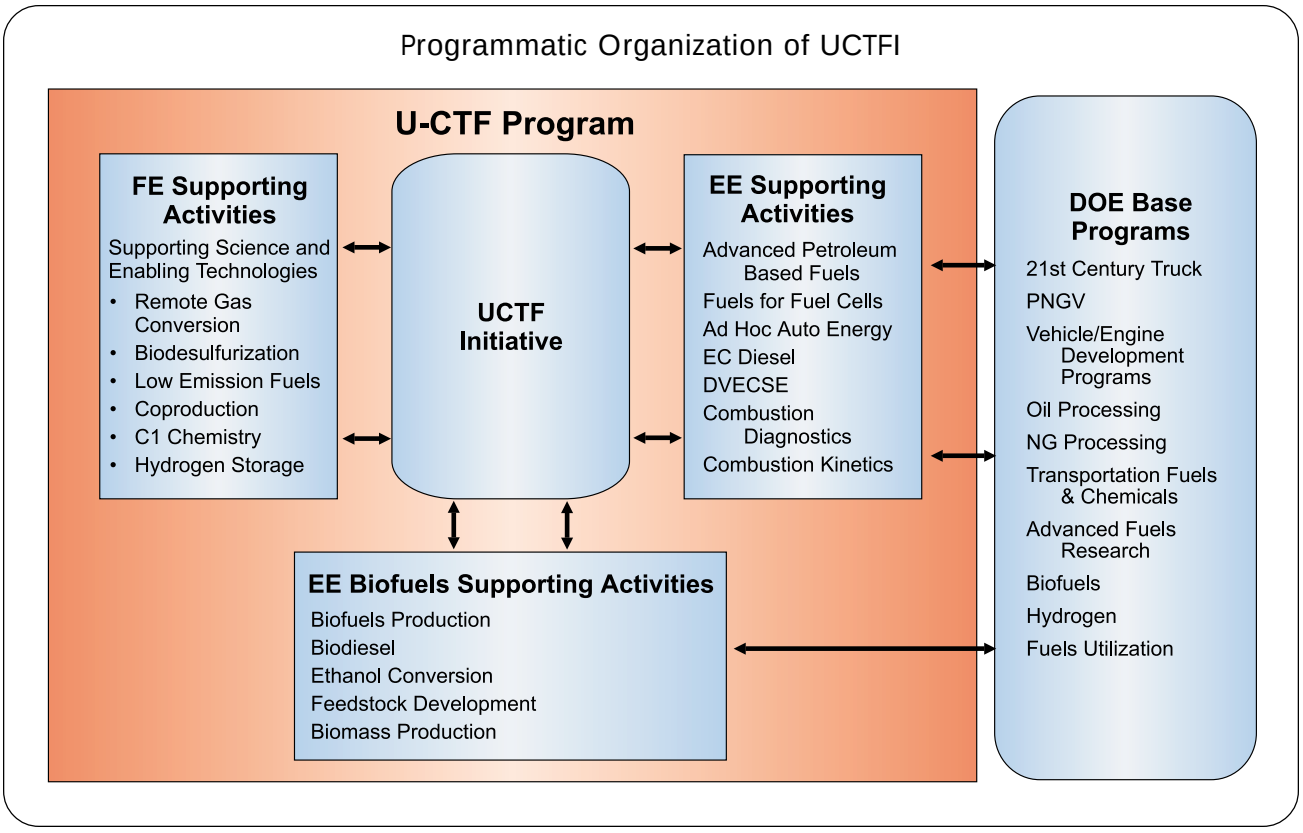
and coal fuels programs that focuses on achieving the common vision of partnering with the U.S. energy industry to meet the growing demand for cleaner transportation fuels.

FE, in partnership with the Office of Energy Efficiency and Renewable Energy's (EERE) Office of Transportation Technologies (OTT), is working toward an integrated approach for ultra-clean fuels development, engine optimization, and post combustion emission controls to achieve significantly higher transportation vehicle efficiency and reduced regional tailpipe emissions. FE is expanding its government partnerships to include the Department of Defense.

The primary objective of the UCTFI is to assist all elements of the U.S. refining and transportation industries in eliminating concerns associated with the use of fossil fuels for transportation purposes. This integrated FE activity has the common goal of promoting the production of ultra-clean fuels from a diversity of resources including conventional and heavy crudes, bottom-of-the-barrel refinery products (residuals and petroleum coke), natural gas, coal, biomass, and other carbonaceous feeds. The partnership will also make more effective use of the skill mix, resources, and synergy among the programs. The result will be more efficient leveraging of federal government and private sector resources, and the more rapid commercialization and deployment of these fuels.

During 1999, workshops and meetings were held with several companies and individuals to structure a government/industry partnership that would address the burdens being placed on fuel producers. Concurrently, discussions with OTT provided the basis for DOE EERE-FE collaboration on a major solicitation that was issued in February 2000.

The UCTFI solicitation encompasses three R&D areas that will be



pursued over five years. The first, and core part of UCTFI, is directed toward systems-oriented R&D projects that will lead to the production of sufficient quantities of fuel to validate performance and emissions goals. Fuels testing will be done in collaboration with OTT. The second focus area is on development of advanced unit operations/processes for producing ultra-clean transportation fuels. The third focus area emphasizes the development of new and innovative emissions control systems.

On September 21, 2000, eight proposals were selected for award. Three research teams proposed advanced refinery processes, while one team proposed an advanced synthesis gas production process. Two other teams proposed to produce F-T fuels and/or dimethyl ether from synthesis gas. Yet another team proposed a new system for emissions control while the eighth and final team proposed a novel hydrogen production process. Additional information on these proposals can be found on the Fossil Energy web site (www.fe.doe.gov).

In addition, an aggressive supporting research program is being set aside for a National Laboratory partnership that will focus on examining some of the key scientific issues (reaction chemistry, materials, etc.) associated with the conversion of natural gas, petroleum, and coal to ultra-clean transportation fuels. The goal of the UCTFI is to develop and deploy technologies that will produce ultra-clean-burning transportation fuels for the 21st century from both petroleum and non-petroleum resources. These fuels will:

- Enable vehicles to comply with future emissions requirements;
- Be compatible with existing liquid fuels infrastructure;
- Enable vehicle efficiencies to be significantly increased, with concomitantly reduced CO_2 emissions;
- Be obtainable from a fossil resource, alone or in combination with other hydrocarbon materials such as refinery wastes, municipal wastes, and biomass; and
- Be cost competitive with current fuels.

Early Entrance Coproduction Plant

The Early Entrance Coproduction Plant initiative examines the feasibility of coproduction technology where transportation fuels, chemicals, electric power, process heat, and other products are coproduced in one facility from various feedstocks. This initiative is part of a joint effort with the gasification technologies program area under the C&PS Central Systems program. In these studies, teams will pursue industry/government cost-shared research and engineering studies that will be directed toward privately funded design, construction, and operation by 2007 of first-of-a-kind commercial facilities that coproduce multiple products. These activities will help industry teams refine their strategies, reduce technical risk, and define economic and environmental requirements.

The "First Step" to Tomorrow's Fuels

The ultimate objective of the EECP initiative is an energy facility that will extract virtually every useable molecule of energy from a range of fuels—coal, biomass, municipal wastes, or possibly various mixtures of these fuels. The following describes the first projects chosen by C&PS to further the EECP concept. NETL will oversee the projects.

Waste Management and Processors, Inc. (WMPI), Frackville, Pennsylvania, and its team will assess the feasibility and economics of a plant that converts coal residue into premium transportation fuels and electricity. Using coal waste not only provides a low-cost feedstock, but also benefits the environment by reclaiming land and preventing a potential pollution problem. If the concept proves feasible, the WMPI project team will develop an engineering design package for a plant to be built in Gilberton, Pennsylvania.

Dynegy Power Corporation, Houston, Texas, will evaluate producing power and chemicals from a plant fueled with coal and non-coal feedstocks. Dynegy will apply its gasification technology, which was being demonstrated at the Wabash River integrated gasification combined-cycle plant. Air Products & Chemicals will provide its novel Liquid Phase Methanol process, which produces methanol from coal-derived synthesis gas. Methanex will add its global expertise in producing and marketing chemical-grade methanol products, and Dow Corning and Dow Chemicals will serve as the customers for the methanol. If the concept proves feasible, the team will develop an engineering design package for a plant to be built at the Wabash River site in Terre Haute, Indiana.

Texaco Natural Gas, Inc. (TNGI), Houston, Texas, will combine its gasification technology with Rentech Inc.'s Fischer-Tropsch technology to produce high-quality transportation fuels and electricity from coal and petroleum coke. Texaco will use results from this project to determine the best configuration for commercial implementation of the integrated technology. If the concept proves feasible, TNGI's team will develop an engineering design package for a plant to be built at one of several sites.

Solid Fuels and Feedstocks

The Solid Fuels and Feedstocks program area is focused on activities to develop advanced technologies for the production of environmentally acceptable solid fuels and tailored carbon feedstocks.

The objectives of the Solid Fuels and Feedstocks program area are to: (1) develop and verify innovative technologies to improve the overall efficiency, economics, and environmental performance of energy utilization systems; (2) reduce environmental impacts associated with the generation of greenhouse gases and HAPs from coal utilization; (3) permit greater recoveries of useful energy in mined coal; (4) encourage the recovery of previously lost carbon raw materials from waste piles and tailing ponds; and (5) support the development of a technology that produces premium carbon and industrial products.

The product of Solid Fuels and Feedstocks research consists of a suite of advanced technologies that are highly efficient and cost-effective in converting raw solids into finished fuel and feedstocks suitable for customer needs. These technologies include a wide variety of processes that improve production, upgrading, handling, and transporting of various solid fuels. The range of solid fuels available for use is extensive and includes coal, alone or in combination with biomass, rubber, plastics, industrial residues, municipal solid wastes, and other solid wastes.

The Solid Fuels and Feedstocks program area is expected to lead to development of carbon products that improve fuel efficiency. New technologies will facilitate the production of lightweight carbon products from coal to be used in airplanes, space vehicles, and the eight million passenger cars, lightweight trucks, passenger vans, and sport utility vehicles the United States produces each year. These technologies can help reduce transportation vehicle weight and yield major improvements in fuel efficiency and environmental quality.

Other research activities include development and demonstration of coal preparation, mild gasification, and industrial technologies. In the area of mild gasification, systems are employed which are simple, low-cost processes that, through coal pyrolysis, create a broad spectrum of useful, environmentally acceptable and economical products. These products fall into three categories: gases, liquids, and solid char.

Mild gasification centers on advanced, integrated processes to develop these products into value-added fuels, chemicals, and industrial products. Char, for example, can be upgraded into carbon black, activated carbon, and specialty fuels. Liquids can be fractioned or catalytically cracked or hydro-treated to produce chemical feedstocks, carbon electrodes, octane enhancers, and diesel-fuel blenders.

NETL'S Solids Processing Research Facility is a one-of-a-kind, state-of-the-art center. Located in Pittsburgh, Pennsylvania, it is used to test a wide variety of advanced coal cleaning, processing, and handling methods.

Environmental Solid Fuels

Research in this area involves developing innovative methods for recovering usable fuels from materials that otherwise would be discarded at coal cleaning plants or utility power stations. Projects address the estimated 2–3 billion tons of coal fines that lie in waste impoundments at coal mines and washing plants around the country, the approximately 30 million tons of coal that is currently being wasted into ponds each year by active mining operations, and the millions of tons of unburned carbon found in power plant fly ash landfills. Technologies are also being developed that combine coal and biomass or municipal solid waste into clean-burning fuels. Moreover, a method is under development for removing mercury from coal before it is burned, thus preventing the mercury from being released to form a hazardous air pollutant.

Other research in this area that will result in the more efficient use of solid fuels includes pilot-scale testing of an electrostatic separation process for dry, fine-size coal and POC testing of an advanced flotation control system.

Industrial-scale testing of an advanced technology will also be conducted for the production of carbonized slurry fuels for power production from coal, biomass, and waste. Work also will continue on the development of a national coal quality database on trace elements, through cooperation with a broad-based, utility-sector consortium for coal utilization.

Tailored Carbon Feedstocks

The Tailored Carbon Feedstocks activity concentrates on advanced technologies for the development of premium carbon products from coal, and the preparation of specially designed (tailored) feedstocks for the production of advanced transportation fuels and chemicals from coal, biomass, and waste feeds. Current projects focus on economically recoverable carbon through novel coal fines processing devices as well as dewatering/reconstitution systems.

Premium Carbon Industry. The Consortium for Premium Carbon Products from Coal (CPCPC) was established to focus on the development, commercialization, and promotion of technologies needed to produce value-added carbon products from coal and coal-derived feedstocks. The CPCPC is a unique, industry-driven consortium that is being led by the Pennsylvania State University, West Virginia University, and NETL. The CPCPC includes more than 50 members that represent a broad array of industries. The CPCPC identifies, selects, and partially funds projects that are deemed to have near-term potential for producing competitively priced premium carbon products from coal or coal-derived feedstocks. Among the members are manufacturers of specialty carbon and graphite products, activated carbon producers, municipally owned water treatment facilities, carbon fiber and composite producers, aluminum producers, carbon black and coal tar pitch producers, battery manufacturers, coal-fired electric utilities, and academia.

This research could result in new types of carbon-based products and applications such as:

- High-value premium carbon and graphite products;
- High-strength, lightweight materials for improving fuel efficiency/reducing weight of vehicles;
- Advanced feedstocks to reduce hazardous air pollutants, such as mercury;
- Improved rechargeable batteries;
- Fuel cell applications;
- Chemically tailored carbon molecular sieves;
- Adsorbents for water and air pollution control;
- Specialty chemicals and coke; and
- Material for heat-resistant applications.

Advanced Fuels Research

The objective of the Advanced Fuels Research program area is to lead the long-term development of advanced fossil energy technologies that will improve the Nation's economy, enhance energy security, and address relevant environmental and global climate change issues.

The strategy is to discover and apply new understandings of the chemistry and physics of carbon conversion to determine and overcome technical barriers that prevent the development of economically competitive, efficient, and environmentally responsible technologies.

These technologies would be designed to close the carbon cycle while ensuring sustained use of domestic carbon sources for the production of economic transportation and boiler fuels, chemicals, and high-value carbon products.

Carbon Science for the Hydrogen Economy

Hydrogen can be produced from natural gas or other fossil feedstocks. However, improvements in current methods for hydrogen separation from other gases remains a key issue for large-scale production of hydrogen (as in a refinery or Vision 21 plant), and for small-scale purification of hydrogen (as in fuel cell-powered vehicles). For hydrogen to be used widely as a transportation fuel, improvements are needed in hydrogen storage.

Hydrogen separation membrane development and its deployment in membrane reactor technology can offer potential advantages in hydrogen production and purification. An alternative approach is to use the appropriate starting fuels and novel reforming strategies.

There are a number of hydrogen storage technologies in various stages of maturity, but the use of advanced carbon materials offers new and exciting possibilities. Finally, the development of better methods for separating other materials in a refinery environment will be necessary to better control the chemical properties of advanced fuels.

Molecular Modeling/Catalyst Development

Advances in high-speed computing and improved understanding of chemical structures have led to increased use of molecular modeling as a predictive tool for research in chemistry. Applying these methods to processes that use catalysts is particularly challenging, but has enormous promise. The Advanced Fuels Research program area, through NETL's Ultra-Clean Fuels Science and Technology research, will investigate the use of computational science to improve the F-T process, hydrogenation, and hydrogen interactions with surfaces. The work will be conducted in collaboration with the University of Pittsburgh, Carnegie Mellon University, and Sandia National Laboratory.

Ion Transport Membranes

Ion transport membranes (ITM), coupled with F-T reactors, produce synthesis gas and hydrogen from natural gas. An artist's rendering of the ITM process is shown above.

C-1 Chemistry: Consortium for Fossil Fuel Liquefaction Science (CFFLS)

The CFFLS is a five-university research consortium with participants from the Universities of Kentucky, Pittsburgh, Utah, West Virginia, and Auburn. Since 1986, the CFFLS has been engaged in research on the development of alternative sources for transportation fuel. Currently, the CFFLS research program, through a recent research grant from DOE, is focused on "C-1" chemistry. C-1 chemistry is essentially the conversion of single-carbon-bearing molecules — such as those that make up natural gas, carbon dioxide, or synthesis gas — into valuable liquid and other products.

Historically, much of the technical community's C-1 chemistry research has focused on a specific category of chemical reactions called the F-T process. One of the consortium's tasks will be to study an F-T process to generate oxygenated fuels using an iron-based catalyst.

The consortium's main effort, however, will be to carry out a first-of-a-kind, nationally coordinated research program on innovative chemical processes that may not follow the traditional F-T pathway. For instance, a better understanding of new types of C-1 chemistry could not only lead to lower-polluting transportation fuels, but also to the increased use of fuel cells — which operate using the hydrogen of carbon-containing materials — in automobiles and in stationary power plants. C-1 chemistry might also reveal ways to use carbon dioxide to convert natural gas into fuels and chemicals, perhaps providing a long-range option for dealing with climate change concerns.

Industry Research on Clean Fuels and Chemicals from Coal

In late 1999, four U.S. companies received research contracts from DOE's Advanced Fuels Research program area to develop and test advanced technologies for producing clean fuels and high-value chemicals from coal. Administered by NETL (with partial funding from DOE's Office of Energy Efficiency and Renewable Energy), the three-year projects are expected to provide new insights into technologies that future energy facilities can use to produce ultra-clean fuels that can help reduce air pollution and lower greenhouse gas emissions. The awarded projects are:

- **Research Triangle Institute, Research Triangle Park, North Carolina**, will develop and test an advanced system for maximizing premium-quality diesel fuel. The system will be based on the F-T process and will attempt to boost the proportion of diesel fuel and lower manufacturing costs by processing the coal gases in high-pressure, fixed bed columns filled with cobalt- and iron-based catalysts.
- **Energy and Environmental Research Corporation, Orange County, California**, will develop an advanced process capable of processing synthesis gas made in a coal gasifier into high-purity hydrogen and a concentrated stream of carbon dioxide that can be disposed of more easily through carbon sequestration techniques.
- **Media & Process Technology, Inc., Pittsburgh, Pennsylvania**, will use a new generation of inorganic (silicon carbide) membranes to separate hydrogen from the gases produced by a coal gasifier. Using data from the separation experiments, a process feasibility study will estimate the economic benefit of silicon carbide membranes in gasification-based power generation applications.
- **Hydrocarbon Technologies, Inc., Mercer County, New Jersey**, will study ways to increase the mechanical strength of catalysts used to convert coal gases into liquid fuels and chemicals. Researchers will develop a process for coating the catalysts with a strong, outside carbon shell. Based on the test results, an economic assessment will be prepared to compare the cost of using the carbon-coated catalyst and the uncoated catalyst in new advanced fuels production plants.

Liquid Phase Methanol Process

In recent years, many of the plastic handles of toothbrushes and screwdrivers have been made from an unusual source. Similarly, the plastic for some photographic film has had the same origin. The common feedstock? Coal gas — a mixture of valuable gaseous chemicals that can be formed by breaking apart coal with high temperatures and pressures.

Many of these products have been made — and are continuing to be made — at the Eastman chemical complex in Kingsport, Tennessee. Since the late 1970s, when natural gas was thought to be in short supply, the company has been gasifying coal to the chemical constituents that can be recombined into a variety of liquid and solid products. One of the products is methanol, which can be used directly as a fuel or as the intermediary for a wide array of petrochemical products, such as plastics.

For nearly a decade, the Kingsport plant relied solely on a conventional "dry" process to transform coal gas into methanol and other products. The coal gas would be blown through a bed of solid catalysts, which aid the chemical reactions that produce the desired products. In the mid-1980s, however, a new coal gas-to-methanol process was ready to be tested. It was a "liquid phase" process; the catalyst particles were suspended in a liquid-filled vessel through which the coal gases would be bubbled.

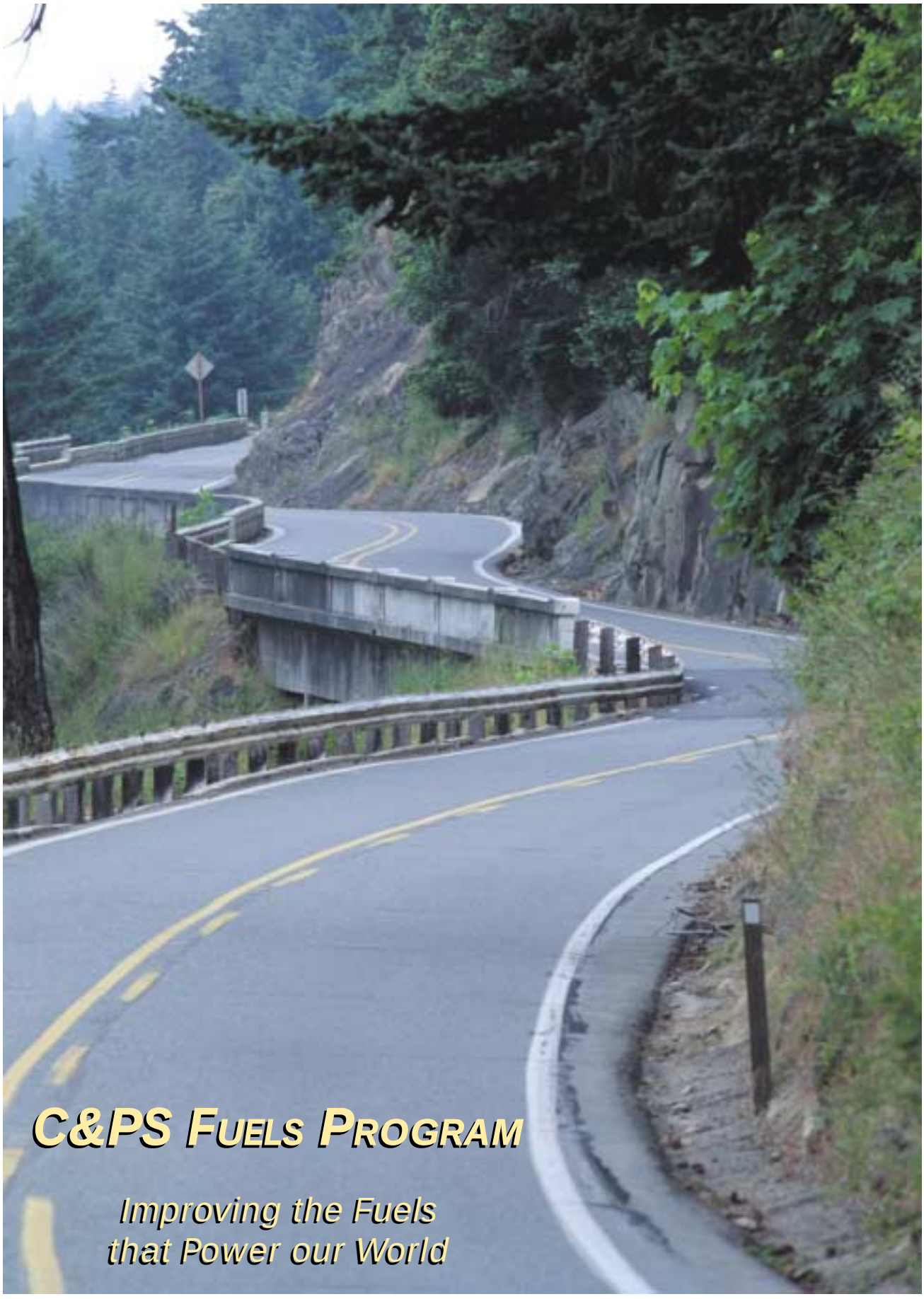
LPMEOH™ 80,000 gallon-per-day demonstration unit at Eastman Chemical Company's Kingsport, Tennessee Facility

Beginning in 1981, DOE invested over $30 million in research and development of the Liquid Phase Methanol Process technology. The original process development work was performed at DOE's 3,200 gallon-per-day Laporte, Texas facility.

In 1989, the Liquid Phase Methanol technology was selected by DOE for demonstration in the third round of the CCT program. The Air Products Liquid Phase Conversion Company, L.P., a partnership between Air Products and Chemicals, Inc. and Eastman Chemical Company, was formed to complete the design, construction, and operation of the commercial-scale plant at Eastman's chemicals-from-coal complex in Kingsport, Tennessee.

Since startup of the unit in April 1997, overall availability has exceeded 96 percent, while calendar year 1998 achieved 99.7 percent availability. Over 66 million gallons of methanol have been produced to date. Due to this success, the project was recently extended an additional 15 months (from December 28, 2001, until March 31, 2003).

The Air Products' Liquid Phase Methanol™ demonstration plant may be the forerunner of either future stand-alone liquids production facilities or, more likely, the liquids-producing module of a multi-product energy plant such as DOE's Vision 21 plant.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